26 April 2001

STATEMENT OF WORK (SOW)

FOR

REDESIGN, TESTING, AND PRODUCTION

OF THE

A/S32P-23 CRASH FIRE RESCUE TRUCK HUB ASSEMBLY

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1. SCOPE. This SOW covers engineering analysis, redesign, and test of the A/S32P-23 (P-23) Crash Fire Rescue (CFR) Truck suspension, focusing on the hub assembly. It also covers an option for production quantities of redesigned P-23 hub assemblies.

1.1 Background. The Air Force has a fleet of 250 P-23 CFR Trucks that entered service between 1994 and 1996. Teledyne Vehicle Systems (TVS) designed and produced most of the P-23s. Late in the production of the vehicles, TVS was sold to General Dynamics Land Systems (GDLS). These trucks have four axles, arranged in two sets of tandem axles. The front tandem axles steer, while the rear tandem axles do not; all axles drive. The P-23 has a fully independent suspension system, using the same double wishbone suspension at all eight wheel positions, differing only in the steering provisions for the front axles. The stub axle, essentially a spindle, is a structural component of this suspension system. To date, at least 98 stub axles have cracked or fractured. In several instances, a wheel and hub assembly separated from a P-23. In addition, there have been a number of porous and/or cracked hub housings; the hub housing is another part of the hub assembly.

1.1.1 Failure analyses. The WR-ALC Materials Analysis Team (WR-ALC/TIEDM) performed failure analyses on a number of cracked or fractured stub axles; the results are documented in seven reports. WR-ALC/TIEDM also performed failure analyses on several hub housings; the results are documented in three reports.

1.1.2 Structural analysis of original stub axle design. The WR-ALC Structures Analysis Team (WR-ALC/TIEDD) performed a structural analysis of the original stub axle design; it is documented in a report.

1.1.3 Strain gage testing. Strain gage testing of the stub axle was conducted by Battelle Memorial Institute (Battelle) under Contract No. F09603-95-D-0180, Delivery Order No. 0007. Throughout this SOW, this effort will be identified as the "Battelle Test." The test is documented in a test report.

2. APPLICABLE DOCUMENTS. The following documents are applicable to the SOW to the extent specified herein.

2.1 Analyses, test procedures, and test reports.

Meyers, V. Cliff, "Failure Analysis of P-23 Fire Truck Wheel Assembly Hub", Report No. 98-MFA-015, WR-ALC/TIEDM Materials Analysis Team, 11 May 1998.

Meyers, V. Cliff, "Failure Analysis of P-23 Fire Truck Wheel Assembly Stub Axle", Report No. 98-MFA-016, WR-ALC/TIEDM Materials Analysis Team, 20 Jul 1998.

Meyers, V. Cliff, "Failure Analysis of P-23 Fire Truck Wheel Assembly Stub Axle", Report No. 98-MFA-020, WR-ALC/TIEDM Materials Analysis Team, 17 Jun 1998.

Meyers, V. Cliff, "Failure Analysis of P-23 Fire Truck Wheel Assembly Stub Axle", Report No. 98-MFA-024, WR-ALC/TIEDM Materials Analysis Team, 08 Jul 1998.

Meyers, V. Cliff, "Failure Analysis of P-23 Fire Truck Wheel Assembly Hub Housing", Report No. 98-MFA-025, WR-ALC/TIEDM Materials Analysis Team, 15 May 1998.

Meyers, V. Cliff, "Failure Analysis of P-23 Fire Truck Wheel Assembly Stub Axle", Report No. 98-MFA-028, WR-ALC/TIEDM Materials Analysis Team, 11 Jun 1998.

Meyers, V. Cliff, "Failure Analysis of P-23 Fire Truck Wheel Assembly Hub Housing", Report No. 98-MFA-030, WR-ALC/TIEDM Materials Analysis Team, 26 May 1998.

Meyers, V. Cliff, "Failure Analysis of P-23 Fire Truck Wheel Assembly Stub Axle", Report No. 98-MFA-032, WR-ALC/TIEDM Materials Analysis Team, 01 Jul 1998.

Meyers, V. Cliff, "Failure Analysis of P-23 Fire Truck Wheel Assembly Hub Housings", Report No. 98-MFA-062, WR-ALC/TIEDM Materials Analysis Team, 18 Mar 1999.

Meyers, V. Cliff, "Failure Analysis of P-23 Fire Truck Wheel Assembly Stub Axle", Report No. 98-MFA-130, WR-ALC/TIEDM Materials Analysis Team, 12 May 1998.

Register, Daniel C., "Structural Analysis Report P-23 Fire Truck Stub Axle", Report No. DTA-TR-98-004, Project No. DTA98-LE-001, Structures Analysis Team, WR-ALC/TIEDD, May 1998.

"Reliability and Engineering Analysis of the P-23 CFR Truck Stub Axle – Test Procedures Document", Contract No. F09603-95-D-0180, Delivery Order No. 0007, 16 Apr 1999.

"Reliability and Engineering Analysis of the P-23 CFR Truck Stub Axle – Final Test Report", Contract No. F09603-95-D-0180, Delivery Order No. 0007, 29 Feb 2000.

2.2 Technical Orders (T.O.s).

36A12-8-17-11	Operation and Operator Maintenance Instructions Crash Fire Rescue Truck Basic: 1 October 1993
36A12-8-17-12	Maintenance and Overhaul Crash Fire Rescue Truck Basic: 1 October 1993
36A12-8-17-14	Illustrated Parts Breakdown Crash Fire Rescue Truck Basic: 2 February 1996

2.3 Drawings.

26-0402-00	Assembly, Hub

26-0402-04 Housing, Hub

26-0402-06 Axle, Stub

2.4 Other publications.

American Society for Testing and Materials (ASTM)

ASTM E 1049-85 Standard Practices for Cycle Counting in Fatigue Analysis

(Application for copies should be addressed to the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken PA 19428.)

Society of Automotive Engineers (SAE)

AMS-STD-2175 Castings, Classification and Inspection of

(Application for copies should be addressed to the Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale PA 15096.)

3. REQUIREMENTS.

3.1 General. The contractor shall plan and conduct the engineering analyses, redesign, and test in accordance with this SOW. The contractor shall provide program management and logistics support management as required to support this effort.

3.1.1 Definitions.

3.1.1.1 Dyess Composite Route. The Dyess Composite Route is defined by Table 9-3 of the Battelle Final Test Report (Normal Operation Route 1 (Table 7-6) with the addition of the indicated numbers of discrete events)).

3.1.1.2 Miner's rule. Miner's rule is a method of predicting whether a part will fail due to fatigue when subjected to specified stress history. Mathematically, it can be expressed as:

$$D = \sum_{i=1}^{k} \frac{n_i}{N_i},$$

where:

D is the damage number,
n is the number of cycles of stress and
N is the number of cycles to failure at that stress level.

A damage number of 1.0 is the generally accepted criterion for whether or not the part will experience a fatigue failure; however, parts may fail at damage numbers as low as 0.5 and may survive until the damage number approaches 30.0.

3.1.1.3 Rainflow cycle counting. Rainflow cycle counting is a standard procedure used for counting cycles for fatigue analysis. The detailed methodology shall be in accordance with 5.4.4 of ASTM E 1049-85.

3.1.2 Criteria for design. The stub axle shall be designed for at least 24,000 miles of normal operation without failure resulting from fatigue; overload, shock or other phenomena leading to brittle fracture; corrosion; or any degradation that would render the stub axle unfit for service. For structural analysis and strain gage testing purposes, the design is considered acceptable if the damage number, which shall be calculated using Miner's rule, is less than or equal to 1.0 for 24,000 miles of the Dyess Composite Route. The rainflow cycle counting algorithm shall be used to produce strain/occurrence histograms. Appropriate safety factors, including casting factors, shall be used in calculations of margins of safety. Appropriate fatigue strength reduction factors, for surface finish, geometry, or other stress concentrations, shall used in calculations of material properties. Casting quality shall be at least Grade C of SAE AMS-STD-2175 for the entire casting, and shall be at least Grade B in the planetary post area.

3.1.2.1 Design loads. The contractor shall develop design loads from the data collected during the strain gage tests, supplemented by other analyses as necessary. Design loads shall include both static and dynamic forces; dynamic forces shall be resolved into mean and alternating forces. Appropriate force/occurrence histograms shall be developed that, when analyzed using the methodology and material properties of the Battelle Final Test Report, reproduce the Battelle calculated damage numbers within ± 10 percent. The Government reserves the right to revise the proposed design loads.

3.1.2.2 Material properties. If the current stub axle materials and manufacturing processes are used, the contractor shall utilize the material properties developed in the Battelle Test for design and analysis purposes. Material properties for all other materials and/or manufacturing processes shall be developed using the same methodology as used in the Battelle Test. The Government reserves the right to revise the proposed material properties.

3.1.3 Proprietary rights.

3.1.3.1 Proprietary rights for existing drawings. Timoney Research Ltd, a member of the Timoney Technology Group, originally designed the hub assembly and its component parts; Timoney Research Ltd has the proprietary rights to the drawings. The contractor shall provide written permission from Timoney Research Ltd prior to the release of any of these drawings by the Government. This permission shall also allow the contractor to manufacture production quantities of the redesigned hub assemblies, if the production option is exercised. It is solely the contractor's responsibility to obtain this permission from Timoney Research Ltd, whether by licensing agreement or other means.

3.1.3.2 Proprietary rights resulting from the performance of the requirements of this SOW. The contractor shall not assert any proprietary rights for any of the products resulting from the performance of the requirements of this SOW.

3.2 Design.

3.2.1 Stub axle design. The contractor shall redesign the stub axle in accordance with 3.1.2. The redesign may include, but is not limited to, changes in material, manufacturing processes, machining, or configuration. In addition, provisions for the Central Tire Inflation System (CTIS) shall be deleted. There is no requirement for the new stub axle to be interchangeable with the original stub axle.

3.2.2 Hub housing design. The contractor shall redesign the hub housing and/or incorporate improved foundry processes to minimize the likelihood of porosity or shrinkage defects. The contractor shall revise the drawing to require that the casting be at least Grade C of SAE AMS-STD-2175 and to require that eddy current examination be performed at the circumferential groove area on the mounting flange of each housing to inspect for cracks or linear porosity open to the surface. Further redesign may be performed, as there is no requirement for the new hub housing to be interchangeable with the original hub housing.

3.2.3 Hub assembly design. The contractor shall redesign the hub assembly to incorporate the redesigned stub axle and hub housing and to eliminate the CTIS provisions. Further redesign may be performed, as there is no requirement for the individual components of the new hub assembly to be interchangeable with the components of the original hub assembly. The redesigned hub assembly shall be form, fit, and function interchangeable with the hub assembly with the exception of the CTIS provisions.

3.3 Structural analysis. The contractor shall perform a structural analysis of the redesigned stub axle to demonstrate compliance with 3.1.2. Finite element analysis (FEA) shall be used, with a mesh suitable for accurate results at high stress areas of the stub axle.

3.4 Testing.

3.4.1 Prototype production. The contractor shall fabricate prototype redesigned hub assemblies for testing purposes. If the bench test option is exercised, the contractor shall fabricate at least 14 prototype hub assemblies; otherwise, at least 11 shall be fabricated.

3.4.2 First article testing. Two prototype hub assemblies shall be provided to Robins AFB for first article testing, which shall be performed by the Government. One shall be disassembled; testing shall include, but not be limited to, material and casting quality, tensile strength, dimensions, etc. The other shall be subjected to a visual inspection as an assembly.

3.4.3 Trial installation. The contractor shall install prototype hub assemblies at all eight positions of a P-23 to ensure form, fit, and function interchangeability. The trial installation shall be performed at Moody AFB GA.

3.4.4 Bench test. If the bench test option is exercised, the contractor shall design and fabricate a test fixture and cycle three test samples to simulate 100,000 miles of the Dyess Composite Route or to complete fracture. The input loads shall be correlated to reproduce the strain/occurrence histograms recorded in the Dyess Composite Route.

3.4.5 Strain gage test. The strain gage test shall be conducted to verify that the redesigned stub axle is adequate for normal operation at the third axle position. The intention is to reproduce Phase I of the Battelle Test as closely as is reasonable, except as specifically stated herein. The Battelle test was performed using a new set of tires; therefore, the contractor shall provide a new set of tires that will be installed on the test vehicle by the Government. The new tires are to remain on the vehicle at the conclusion of the test program.

3.4.5.1 Test site. The test site shall be Goodfellow AFB TX.

3.4.5.2 Test cycle. The test cycle shall be the Dyess Composite Route.

3.4.5.3 Test data. The contractor shall collect at least the same data as was recorded in Phase I of the Battelle Test, except that strain gage data is only required at the third axle position on the right (curb) side of the P-23.

3.4.5.4 Instrumentation. The contractor shall position at least 12 strain gages at the third axle position on the right side of the P-23 (a tri-axial gage is considered three uni-axial gages). The contractor shall recommend locations to be gaged, considering high stress areas as indicated by FEA, classical structural analysis, and/or failure analysis; the intention is to duplicate those locations gaged for the Battelle Test as closely as possible. The Government will make the final decisions as to gage locations and positions. The contractor shall instrument the P-23 to record the strain gage and other data identified in 3.4.5.3.

3.4.5.5 Data recording. The contractor shall record the strain gage and other data identified in 3.4.5.3 while subjecting the P-23 to the test cycle defined in 3.4.5.2. P-23 operation shall be in accordance with T.O. 36A12-17-11.

3.4.5.6 Data reduction. The contractor shall use the rainflow cycle counting algorithm to produce strain/occurrence histograms for each gage for each test cycle. The data identified in 3.4.5.3 shall be provided in appropriate formats determined by the contractor and coordinated with the Government.

3.5 Development of technical data.

3.5.1 Engineering data. The contractor shall develop, produce, and maintain a Technical Data Package (TDP) that accurately depicts the final product. The TDP shall provide the design, engineering, manufacturing, testing, and quality assurance requirements information necessary to enable the procurement or manufacture of an interchangeable item that duplicates the physical and performance characteristics of the original product, without additional design engineering effort or recourse to the original design activity.

3.5.1.1 Proprietary markings. The TDP shall not contain proprietary markings other than those contained on the original drawings. Existing proprietary markings shall be maintained unless permission to delete them is obtained from Timoney Research Ltd.

3.5.2 Installation instructions. The contractor shall provide installation instructions suitable for field level installation to replace and check the hub assemblies and associated components.

3.5.3 T.O. changes. The contractor shall provide changes to the T.O.s as required to incorporate the new hub assemblies and associated components. All artwork shall be in the form of line drawings; photographs shall not be provided.

3.6 Production. If the production option is exercised, the contractor shall manufacture production hub assemblies utilizing the redesigned stub axle in accordance with the delivery schedule of the contract.

3.7 Travel. The contractor shall arrange and execute all travel necessary for the performance of the requirements of this SOW.

3.8 Exchange of information and resources. This project is unclassified and the Government may place the final technical data and reports in the public domain. However, the contractor shall not release any information pertaining to this project nor present interim results to any parties outside WR-ALC/LEEV without first obtaining permission from the Contracting Officer's Technical Representative (COTR) through the Procuring Contracting Officer (PCO). No data developed in part or in whole by resources obtained from this project shall be used on any other contract or task without obtaining written permission from WR-ALC/LEEV through the PCO.

3.9 Services required of the Government.

3.9.1 Government furnished data. The Government will provide the contractor with copies or access to the documents listed in 2.1, 2.2, and 2.3. These documents may be in either digital or hard copy format, at the Government's discretion.

3.9.2 Government furnished equipment. The Government will provide the contractor with access to one P-23 CFR Truck for the trial installation (see 3.4.3). The Government will provide the contractor with access to one P-23 CFR Truck for instrumentation (see 3.4.5.4) and data recording (see 3.4.5.5). The contractor shall remove all instrumentation and restore any corrosion protection coatings that were removed to install the instrumentation at the conclusion of data recording. The Government will provide drivers to operate the P-23 for up to eight hours per day during data recording.